EXPERT OPINION REGARDING THE PROPOSED DEWEY-BURDOCK PROJECT ISL MINE NEAR EDGEMONT, SOUTH DAKOTA

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INTRODUCTION

In early March 2010 I was contacted by Lilias Jarding (WMAN) to review an application to the US Nuclear Regulatory Commission for construction of an ISL facility (the Dewey-Burdock Project) for mining uranium near Edgemont, South Dakota. I had previously provided an expert opinion to the Western Nebraska Resources Council (among others) regarding ISL uranium mining near Crawford, Nebraska. I am offering this expert opinion regarding ISL uranium mining near Edgemont because I am concerned that the issues that I raised in the earlier opinion also apply to the proposed Dewey-Burdock Project. As I have stated previously, I am not against uranium mining in fact or principle. This issue isn't about uranium. It's about protecting the region's water supply, and the future inhabitability of southwestern South Dakota and adjacent Nebraska. In this document, I will briefly explain the basis for my concerns.

PROFESSIONAL BACKGROUND

I have 20 years experience studying the rocks and fossils of northwestern Nebraska and adjacent South Dakota. From 1988-1991 I collected fossils from northern Sioux County, Nebraska for my dissertation work. From 1991-1996 I led field parties from the University of Nebraska State Museum while mapping the fossils and geology of the Oglala National Grassland in Sioux and Dawes counties, Nebraska. From 1996-2006 I led teams of geologists from the Nebraska Geological Survey that mapped in detail the surficial geology of most of northwestern Nebraska (a total of 80 1:24,000 quadrangles). The completion of this work frequently required detailed study of equivalent strata in adjacent South Dakota. These maps, including digital versions (ArcInfo) and supporting field notes, are available from the University of Nebraska-Lincoln School of Natural Resources (contact James B. Swinehart). As a direct consequence of this mapping, I have published peer-reviewed articles on the Chadron Formation (Terry & LaGarry 1998), the Brule Formation (LaGarry 1998), the mapping of surficial deposits (Wysocki & others 2000, 2005), and local faults (Fielding & others 2007). From 2006-2008 I continued this work as an Adjunct Professor of Geology at Chadron State College (CSC) in Chadron, Nebraska. During this time I worked with and advised students studying the region's groundwater, surface water, and geologic structures (principally faults). In May 2008, my CSC colleagues and I, along with Chadron residents, scientists from the Nebraska Geological Survey, the United States Geological Survey, the University of Nebraska School of Natural Resources, and the Upper Niobrara-White Natural Resource District, convened "Our Water, Our Future: a Town Hall Meeting." Our consensus opinion was that water shortages and declining water quality are real and worsening problems in northwestern Nebraska and the northern Great Plains region. Since 2008 I have been serving the Oglala Sioux Tribe as an Instructor in the Department of Math, Science, & Technology at Oglala Lakota College (OLC), and since 2009, as co-chair of that department. Since joining the faculty at OLC, I have been working with students and faculty to continue to study the geology, groundwater, surface water, and heavy metal contamination of southwestern South Dakota and the Pine Ridge Reservation. In pursuing these studies, we have formed working partnerships with Chadron State College, the South Dakota Geological Survey, the South Dakota School of Mines and Technology, South Dakota State University, the University of Illinois Urbana-Champaign, the University of Illinois Center for Advanced Materials Purification of Water Systems, the Department of Health Physics at the University of Michigan School of Nuclear Engineering, the University of Washington Burke Museum, and the University of Washington Native American Research Center for Health. Our research has been funded for the next 5 years by the National Science Foundation Tribal Colleges and Universities Program.

THE CONCERNS

My concerns regarding the Dewey-Burdock Project are centered around the problems of secondary porosity in the form of faults and joints, the lack of confinement, artesian flow, and the horizontal flow of water within the uranium-bearing strata. I found the Powertech's environmental report to be poorly referenced overall, but especially parts concerning the geology of the region. The conclusions concerning the geology within the proposed area are based on in-house studies and unpublished theses and reports. It is beyond the scope of this opinion to review the entire scientific literature for the region, but I provide the most readily available recent research. Where appropriate, I also refer to specific sections of Powertech's environmental report to the US Nuclear Regulatory Commission (NRC) for the construction of the Dewey-Burdock Project.

The problem of secondary porosity

Secondary porosity, in the form of intersecting faults and joints, is common in all of the rocks north, east, and south of the Black Hills Dome, especially north of and along the Pine Ridge Escarpment (see Swinehart & others 1985). These faults and joints are generally oriented NW-SE and SW-NE, and are most likely a result of the ongoing uplift of the Black Hills of southwestern South Dakota. Although a few people consider the Black Hills uplift to have ended by the late Cretaceous (~65 Ma), the Black Hills were tectonically active in the late Eocene (Evans & Terry 1994), and continued to fault, fracture, and fold the rocks of northwestern Nebraska and southwestern South Dakota into the middle Miocene (Fielding & others 2007). Based on numerous small earthquakes along the Sandoz Ranch-Whiteclay Fault, the area is still tectonically active (McMillan & others 2006). These earthquakes are relatively mild, and don't significantly damage surface infrastructure. However, even small earthquakes represent shifting and flexing of the earth's crust, and are continuously creating, closing, and redistributing the secondary porosity of the region's rocks. This means that joints incapable of transmitting water one day may be able to transmit water at a later date. These faults and fractures transect all major bedrock units of the region. These faults likely connect the uranium-bearing strata to adjacent aquifers as well as modern river alluvium.

In 2007, Chadron Creek, the stream that supplies water to the city of Chadron, Nebraska, went dry for the first time in the citys' history. Subsequent study of the creek's water flow rates by Chadron State College students suggested that normal amounts of water are flowing from the

Summary of Comments on DEWEY OPINION

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THE CONCERNS

1. The problem of secondary porosity in the form of faults and joints
2. The problem of lack of confinemets
3. The problem of artesian flow
4. The problem of horizontal flow rates

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The problem of secondary porosity

Two issues: intersection faults and joints

On-going seismicity in the Black Hils

springs, but the water is disappearing into deeper alluvium or into fractures in the rock (Balmat & others 2008, Butterfield & others 2008). Following these observations, a Chadron State College graduate student began studying the widespread faults and lineaments of northwestern Nebraska and southwestern South Dakota using data collected by high-flying aircraft, satellites, and the space shuttle (Balmat & Leite 2008). Many of the faults in northwestern Nebraska and southwestern South Dakota persist for tens of miles (Diffendal 1994, Fielding & others 2007). Also, many of the ancient river deposits of the Tertiary strata, along with the alluvium deposited by modern rivers such as the Cheyenne River, the White River, and Hat Creek, follow fault zones because fractured rock erodes more easily. A review of the scientific literature shows that faults and joints are well-known in rocks surrounding the Black Hills, and are known to interconnect major aquifers and the land surface (Swinehart & others 1985, Peters & others 1988, Fielding & others 2007). Powertech's application asserts that although fault zones are known both north and south of the project area (section 3.3.2.1), there are no known faults within the project area and therefore little or no secondary porosity. This is a false perception, because joints (cracks in the rock lacking measurable displacement) are exceedingly common in this region and form the vast majority of secondary porosity and contaminant pathways.

The problem of lack of confinement

In order for ISL mining to be considered safe, the uranium-bearing, mined strata must be isolated from rocks above and below by confining layers. There are three principal pathways through which contaminated water could migrate away from the uranium-bearing strata through adjacent confining layers. The first, and most common, are along joints and faults (see above). Where present, joints and faults penetrate confining layers above and below. The second is through thinning or pinching out of confining layers. In their application to the NRC, Powertech concedes that the upper confining layers thin and there are breaches in the upper confining layers (sections 3.3.2.2, 3.4.3.1.7, 3.4.3.1.10, and 3.4.3.2). The third pathway for mine fluids to breach containment is through perforations made by wells. In Powertech's application, they repeatedly mention "thousands of exploratory wells," along with wells that supply drinking water (the uranium-bearing strata are a local drinking water supply) and water for livestock. In addition, many of these wells are abandoned and most likely improperly plugged (section 3.4.1.2). Once mining begins, and minerals are being extracted, flow pathways within the uranium-bearing rocks will change, potentially creating circumstances in which any one of these wells could allow lixiviant to breach confinement. Once into adjacent water-bearing strata or the land surface, contaminants can enter rivers and flow downstream with each successive rain event, or flow downgradient into other water supplies.

The problem of artesian flow

Artesian flow occurs when there is a hydrologic connection, through faults or highly permeable strata, between groundwater sources and the land surface. The weight of water in overlying strata exerts pressure downward into water within the uranium-bearing strata, which can then be released as artesian water flow where the topographically lower uranium-bearing strata is exposed at the surface, or where it is punctured by drilling. Artesian flow was observed or predicted by Powertech in their Dewey-Burdock Project proposal (sections 3.4.1.2, 3.4.3.1, and 3.4.3.1.7). Artesian flow is most likely where the upper confining layer is perforated by

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Ex. 5 - Deliberative Process (DP)

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Ex. 5 - Deliberative Process (DP)

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The problem of lack of confinement

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The problem of artesian flow

secondary porosity (section 3.3.2.1), poorly constructed or improperly sealed exploration wells (sections 3.3.2 and 3.4.1.2), or thinning or absence of upper confining layers (section 3.4.3.1.7). Artesian flow could transmit lixiviant, the most toxic mineral-laden of waters, onto the land surface (and into Cheyenne River, White River, or Hat Creek alluvium) and discharge large amounts of contaminants into aquifers or faults in a very short time.

The problem of horizontal flow

Confining layers adjacent to uranium-bearing strata limit the unwanted spread of contaminants from an ISL site. However, horizontal flows within the uranium-bearing strata are also of concern. Such flow can rapidly redirect lixiviant or mine waste away from the mine site and into unexpected breaches in the confining layers. In their application to the NRC, Powertech reports horizontal flows within the uranium-bearing strata (the Inyan Kara Group) of up to 35.5 meters/day (Chilson Member, section 3.3.2.2) based on local conditions, and of up to 6,000 ft^2/day (section 3.4.3.1.2) elsewhere in the Black Hills region. Even if secondary porosity, artesian flow, or lack of confinement did not contaminate nearby water supplies, down gradient flow along the Cascade and Chilson anticlines (Rothrock 1931a, 1931b, 1948) would transmit contaminants to the major, mapped faults north of the Pine Ridge in Nebraska in less than 5 years (using the smaller value).

CONCLUDING REMARKS

Based on the arguments presented above, it is my expert opinion that ISL mining in the Edgemont, South Dakota should not be allowed. Artesian flow, the potential lack of confinement due to secondary porosity and drilling, along with potentially high horizontal flow in the uranium-bearing strata indicate that during the course of its operation the Dewey-Burdock ISL Project will most likely contaminate the region with unconfined lixiviant. This contamination could plausibly pollute groundwaters and surface waters southwards into Nebraska and surface waters within the Cheyenne River drainage eastwards into greater South Dakota. Also, based on my reading of Powertech's application, no review of the geologic literature was conducted. In my view, the use of outdated scientific literature, or in this case, a general lack of review of recent study, should not be seen as an opportunity to operate in a knowledge vacuum. Much of the Great Plains region was studied prior to the 1980's and the general acceptance of Plate Tectonics Theory, and therefore generally misrepresents the geologic setting of the region. This was true of the geologic literature used to justify ISL mining near Crawford, Nebraska, and is also true of the data used to justify proposed mining near Edgemont, South Dakota. It is incumbent upon potential ISL operators, as it is with any natural resource consumers, to seek out the most recent research and expert opinions on the geological settings in which they propose to operate.

REFERENCES

Balmat, J. L. & M. B. Leite. 2008. Identification of geological structures from lineaments on remotely sensed images of the Black Hills-Pine Ridge region. Proceedings of the 118th Annual Meeting of the Nebraska Academy of Sciences, p.28.

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The problem of horizontal flow

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In their application to the NRC, Powertech reports horizontal flows within the uranium-bearing strata (the Inyan Kara Group) of up to 35.5 meters/day (Chilson Member, section 3.3.2.2)

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Section 3.3.2.2 is in the Environmental Report.
Statement under Chilson Sandstone section:
Analyses of core samples of these sandstones indicate these
units exhibit high horizontal permeabilities, ranging from 2.6 x 10^{-3} cm/sec to 4.1 x 10^{-3} cm/sec
(2697 millidarcies to 4161 millidarcies).

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CONCLUDING REMARKS

Balmat, J. W., J. L. Balmat, M. J. Culver, A. C. Butterfield, C. A. Kaiser, J. Zweibel, H. E. LaGarry, & M. B. Leite. 2008. Preliminary geology of the Chadron Creek watershed, Dawes County, Nebraska. Proceedings of the 118th Annual Meeting of the Nebraska Academy of Sciences, p.64.

Butterfield, A. C., J. L. Balmat, J. W. Balmat, K. Young, M. Culver, C. A. Kaiser, J. Zweibel, M. B. Leite, & H. E. LaGarry. 2008. Discharge of Chadron Creek, Dawes County, Nebraska. Proceedings of the 118th Annual Meeting of the Nebraska Academy of Sciences, pp. 64-65.

Diffendal, R. F. 1994. Geomorphic and structural features of the Alliance 1^{o} x 2^{o} Quadrangle, western Nebraska, discernible from synthetic-aperature radar imagery and digital shaded-relief maps. Rocky Mountain Geology 30(2):137-147.

Evans, J. E. & D. O. Terry, Jr. 1994. The significance of incision and fluvial sedimentation in the basal White River Group (Eocene-Oligocene), badlands of South Dakota, U. S. A. Sedimentary Geology 90:137-152.

Fielding, C. R., H. E. LaGarry, L. A. LaGarry, B. E. Bailey, & J. B. Swinehart. 2007. Sedimentology of the Whiteclay gravel beds in northwestern Nebraska, USA: structurally controlled drainage promoted by early Miocene uplift of the Black Hills Dome. Sedimentary Geology 202:58-71.

LaGarry, H. E. 1998. Lithostratigraphic revision and redescription of the Brule Formation(White River Group), northwestern Nebraska, pp. 63-92 in (D. O. Terry, Jr., H. E. LaGarry, & R. M. Hunt, Jr., eds.) Depositional environments, lithostratigraphy, and biostratigraphy of the White River and Arikaree Groups (late Eocene to early Miocene, North America). Geological Society of America Special Paper 325, 216 p.

LaGarry, H. E. & L. A. LaGarry. 1997. Geology of the Montrose, Orella, Wolf Butte, Roundtop, and Horn 7.5′ USGS quadrangles, Sioux and Dawes counties, Nebraska. University of Nebraska-Lincoln Conservation and Survey Division Open-file Report 48, 161 p.

McMillan, M. E., P. L. Heller, & S. L. Wing. 2006. History and causes of post-Laramide relief in the Rocky Mountain Orogenic Plateau. Geological Society of America Bulletin 118(3/4):393-405.

Peter, K. D., K. E. Kolm, & T. C. Nichols, Jr. 1988. Lineaments: significance, criteria for determination, and varied effects on ground-water systems – a case history in the use of remote sensing, pp. 46-68 *in* (A. I. Johnson & C. B. Petersson, eds.) Geotechnical Applications of Remote Sensing and Remote Data Transmission. American Society for Testing and Materials, Philadelphia, Pennsylvania.

Rothrock, E. P. 1931. The Cascade Anticline. South Dakota Geological Survey Reports of Investigations 8, 25 p.

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https://books.google.com/books?id=r017dOVaeH4C&pg=PA46&lpg=PA46&dq=Peter,+K.+D.,+K.+E.+Kolm,&source=bl&ots=8oLJMHbMfl&sig=ACfU3U1KOvzWhfgPt4KiIuDgheM4nIVJNA&hl=en&sa=X&ved=2ahUKEwjbwtX7uqfpAhVUZM0KHfWfDk4Q6AEwAXoECAoQAQ#v=onepage&q=Peter%2C%20K.%20D.%2C%20K.%20E.%20Kolm%2C&f=false

Rothrock, E. P. 1931. The Chilson Anticline. South Dakota Geological Survey Reports of Investigations 9, 26 p.

Rothrock, E. P. 1948. Structures in Fall River County. South Dakota Geological Survey Reports of Investigations 62, 64 p.

Swinehart, J. B., V. L. Souders, H. M. DeGraw, & R. F. Diffendal Jr. 1985. Cenozoic paleogeography of western Nebraska, pp. 209– 229 in (R. M. Flores & S. S. Kaplan, eds.), Cenozoic Paleogeography of West-Central United States. Proceedings of Rocky Mountain Paleogeography Symposium 3, Society of Economic Paleontologists and Mineralogists. Denver, Colorado.

Terry, D. O., Jr. & H. E. LaGarry. 1998. The Big Cottonwood Creek Member: a new member of the Chadron Formation in northwestern Nebraska, pp. 117-142 in (D. O. Terry, Jr., H. E. LaGarry, & R. M. Hunt, Jr., eds.) Depositional environments, lithostratigraphy, and biostratigraphy of the White River and Arikaree Groups (late Eocene to early Miocene, North America). Geological Society of America Special Paper 325, 216 p.

Terry, D. O., Jr. 1998. Lithostratigraphic revision and correlation of the lower part of the White River Group: South Dakota to Nebraska, pp. 15-38 in (D. O. Terry, Jr., H. E. LaGarry, & R. M. Hunt, Jr., eds.) Depositional environments, lithostratigraphy, and biostratigraphy of the White River and Arikaree Groups (late Eocene to early Miocene, North America). Geological Society of America Special Paper 325, 216 p.

Wysocki, D. A., P. J. Schoeneberger, & H. E. LaGarry. 2005. Soil Surveys: a window to the subsurface. Geoderma 126:167-180.

Wysocki, D. A., Schoeneberger, & H. E. LaGarry. 2000. Geomorphology of soil landscapes, pp. E5-E39 in (M. E. Sumner, editor-in-chief) CRC Handbook of Soil Science. Chemical Rubber Company Press.